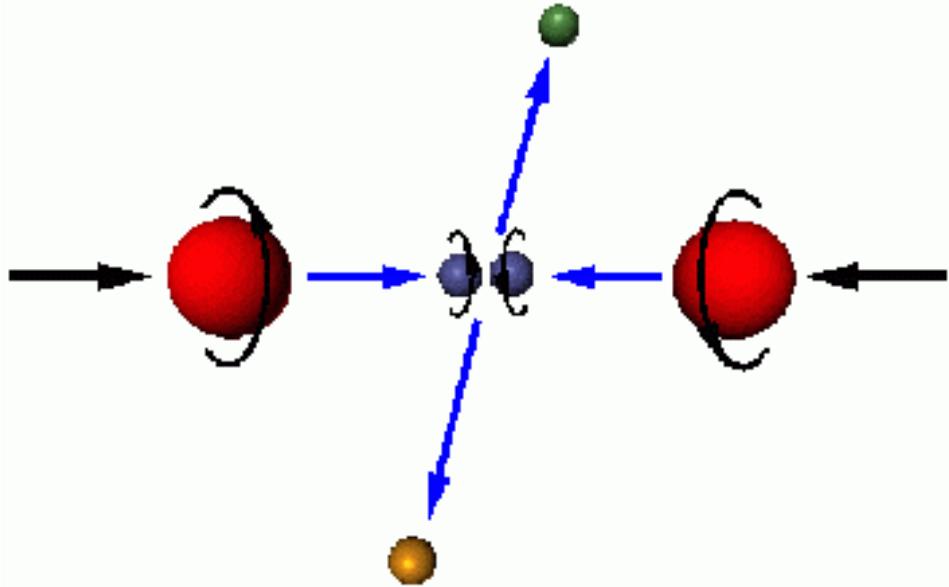


# Exploring the Spin Structure of the Nucleon with PHENIX



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DNP'2001, Oct 2001

# Spin Structure of the Nucleon

What makes up the spin of the proton?

» The quarks?

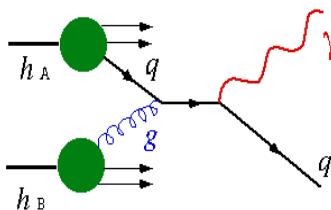
$$\Delta\Sigma = \Delta u + \Delta d + \Delta s + \Delta \bar{u} + \Delta \bar{d} + \Delta \bar{s}$$

$\approx 0.2 \rightarrow$  "spin crisis"

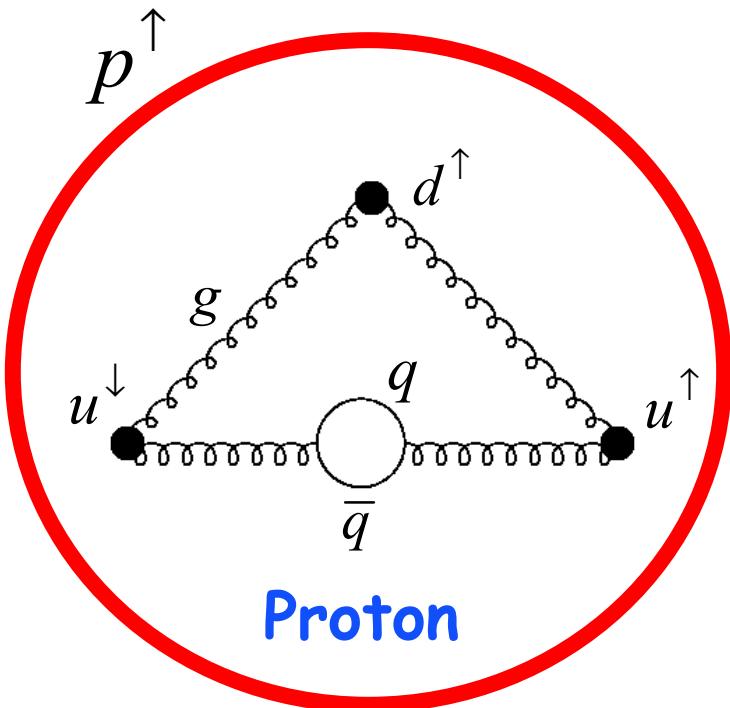
The individual quark flavor contribution can be studying from W decays → RHIC spin

» The gluons?

→ RHIC spin



Spin



Proton

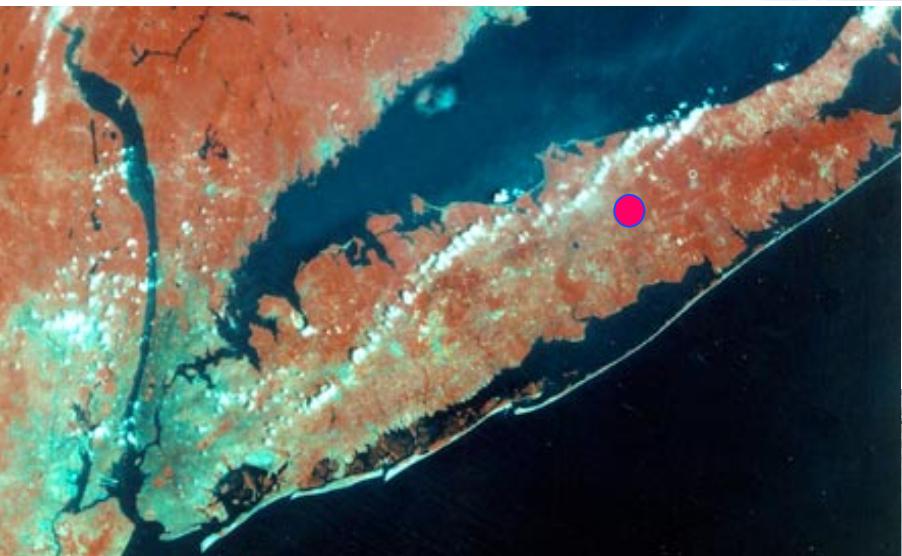
Quark Spin

$$\frac{1}{2} = \frac{1}{2} \Delta\Sigma + \Delta G + L_z$$

Gluon Spin  
Orbital Angular Momentum



# Relativistic Heavy Ion Collider



## Design Parameters:

<u>Performance</u>	<u>Au + Au</u>	<u>p+p</u>
$\sqrt{s_{nn}}$	200 GeV	500 GeV
$L [cm^{-2} s^{-1}]$	$2 \times 10^{26}$	$2 \times 10^{32}$
Cross-section	6 barns	60 mbarn
Interaction rates	1440 Hz	12 MHz

## RHIC Capabilities

- ✓ Au + Au collisions at 200 GeV/u
- ✓ p + p collisions up to 500 GeV
- ✓ spin polarized protons (70%)
- ✓ lots of combinations in species and energy in between

# The PHENIX Detector for Spin

## Philosophy:

- ✓ High rate capability & granularity
- ✓ Good mass resolution and particle ID
- Sacrifice acceptance

### Central Arm Tracking

Drift Chamber, Pad Chambers, Time Expansion Chamber

### Muon Arm Tracking

Muon Tracker

### Calorimetry

PbGl and PbSc (gain balance, level 1)

### Particle Id

Muon Identifier (level 1), RICH, TOF, TEC

### Luminosity Counters/Vertex Detectors

BBC, ZDC, NTC, MVD

### DAQ

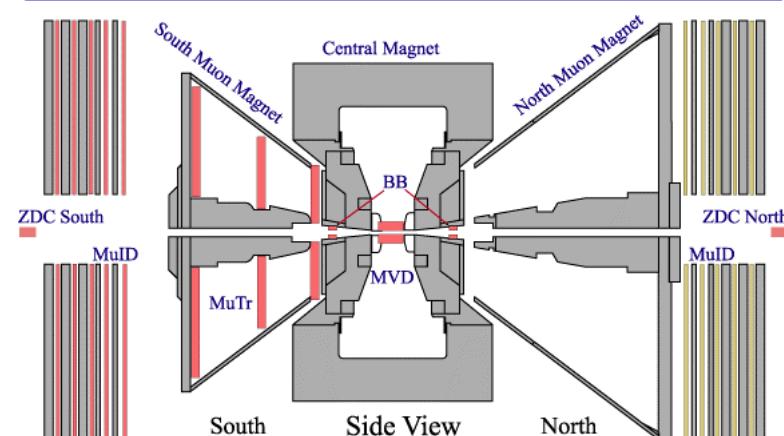
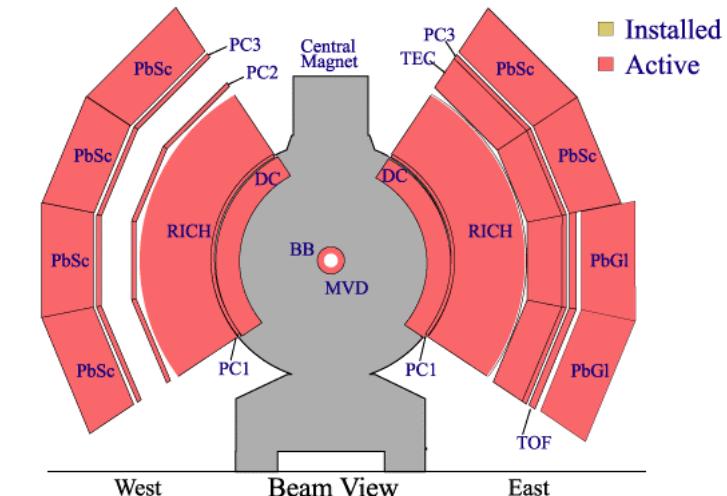
Bandwidth upgrade, event size/data volume

### Trigger

Level 2 (Bandwidth upgrade)

Level 1 (GL1P, muId, EMC/RICH)

PHENIX Detector - Second Year Physics Run



# Proton Spin Structure at PHENIX

## Gluon Polarization

$\Delta G$

$\pi^0$  Production  $A_{LL}(gg, gq \rightarrow \pi^0 + X)$

$\pi^{+/-}$  Production  $A_{LL}(gg, gq \rightarrow \pi^{+/-} + X)$

Heavy Flavors  $A_{LL}(gg \rightarrow c\bar{c}, b\bar{b} + X)$

Direct Photon  $A_{LL}(gq \rightarrow \gamma + X)$

Jet Photon  $A_{LL}(gq \rightarrow \gamma + \text{Jet} + X)$

Jet Jet  $A_{LL}(gq \rightarrow \text{Jet} + \text{Jet} + X)$

## Flavor decomposition

$$\frac{\Delta u}{u}, \frac{\Delta \bar{u}}{\bar{u}}, \frac{\Delta d}{d}, \frac{\Delta \bar{d}}{\bar{d}}$$

## W Production

$$A_L(u + \bar{d} \rightarrow W^+ \rightarrow l^+ + v_l)$$

$$A_L(\bar{u} + d \rightarrow W^- \rightarrow l^- + \bar{v}_l)$$

## Transverse Spin

Transversity  $h_1$ :

$\pi^+, \pi^-$  Interference fragmentation:

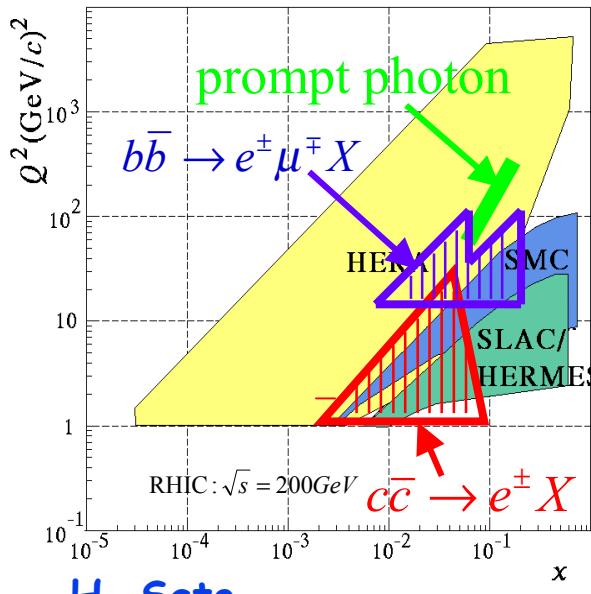
$$A_T(p_\perp p \rightarrow (\pi^+, \pi^-) + X)$$

Single Pion Asymmetries

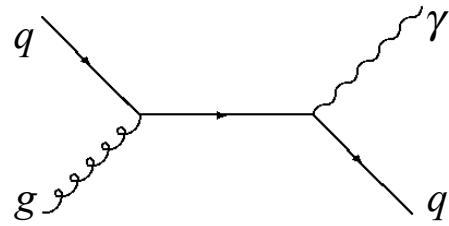
Drell-Yan



# $\Delta G$ in PHENIX



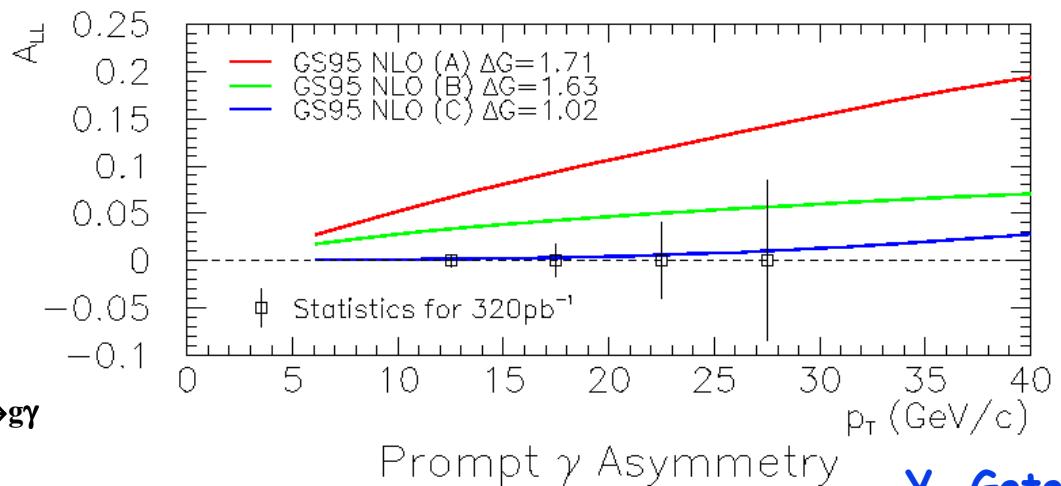
H. Sato  
Direct  $\gamma$  Production



$$A_{LL} \propto \frac{\Delta q(x_A)}{q(x_A)} \otimes \frac{\Delta G(x_B)}{G(x_B)} \otimes a_{LL}^{qg \rightarrow g\gamma}$$

PHENIX is sensitive to several channels that are sensitive to  $\Delta G$

- » Channels have different kinematic coverage
- » Channels have different systematic errors

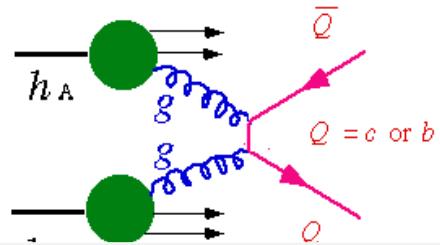


Y. Goto



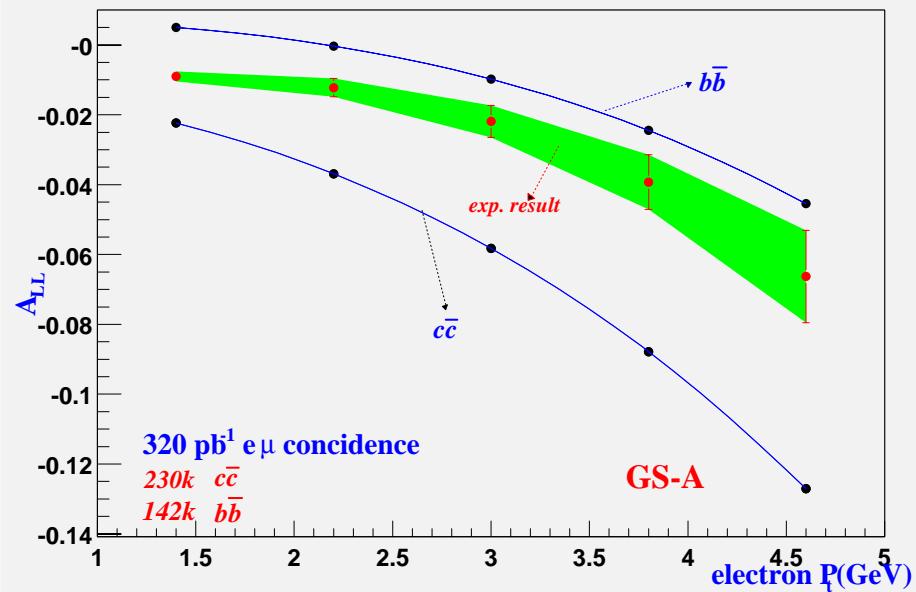
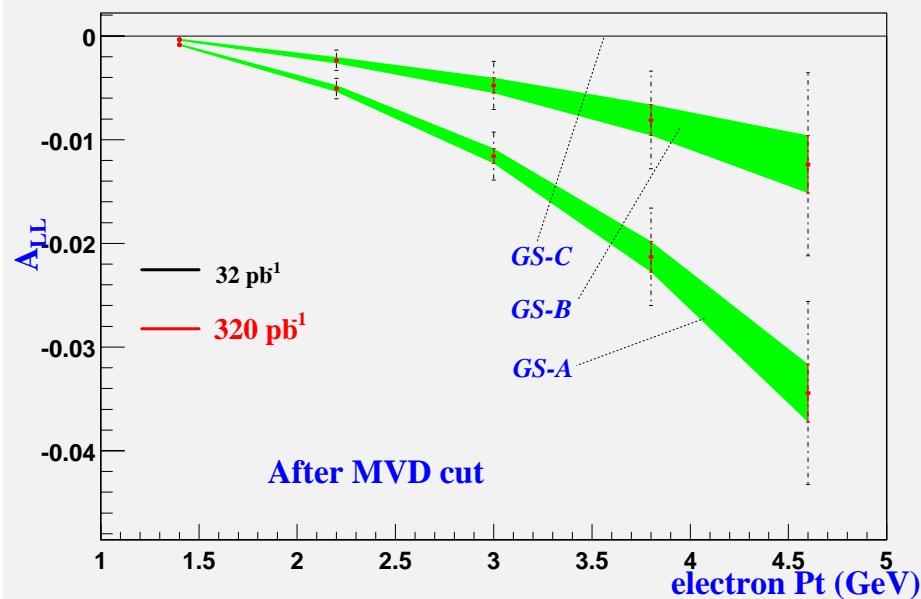
K. Barish  
UC Riverside  
17 Oct. 2001

# $\Delta G$ in PHENIX (heavy flavor)



Tag as: single e, e-mu, e-D coincidence

$$A_{LL} \propto \frac{\Delta G(x_A)}{G(x_A)} \otimes \frac{\Delta G(x_B)}{G(x_B)} \otimes a_{LL}^{gg \rightarrow q\bar{q}}$$



W. Xie and H. Sato



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# Flavor Decomposition

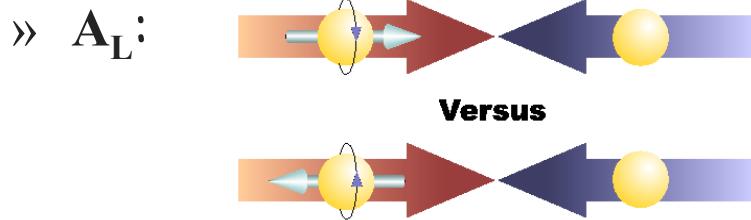
$W$  is Produced through  $V-A$  process

- » Chirality is fixed  $\rightarrow$  ideal for spin structure studies

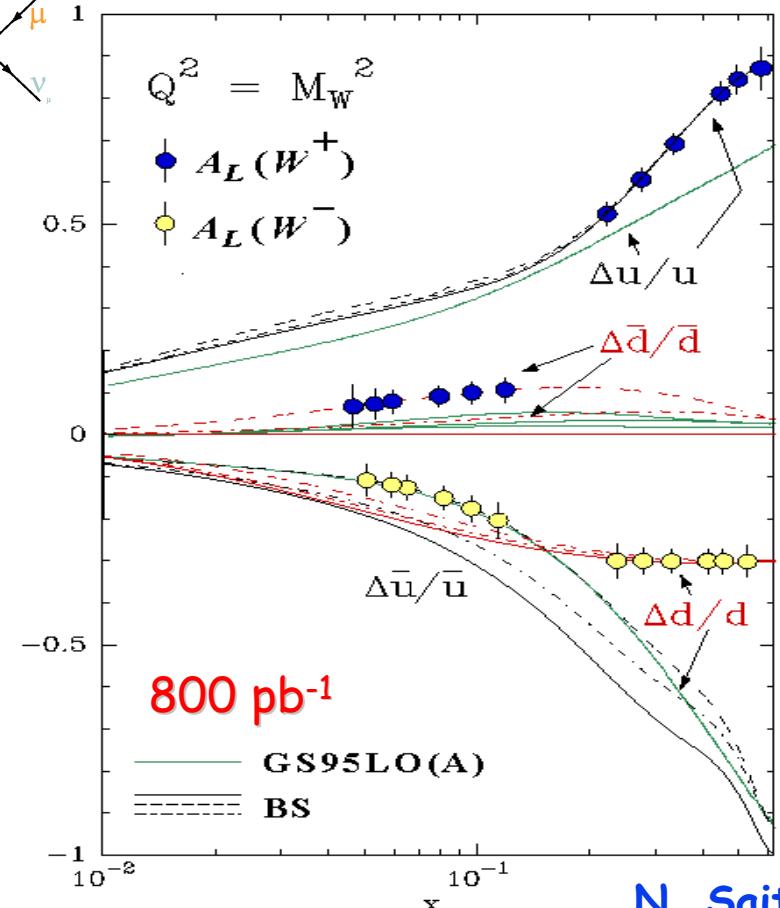
$W$  couples to weak charge  $\sim$  flavor

- » Flavor is almost fixed  $\rightarrow$  ideal for flavor structure studies

Parity Violating asymmetry in  $W$  Production



$$A_L^{W^+} = \frac{\Delta u(x_a)\bar{d}(x_b) - \Delta \bar{d}(x_a)u(x_b)}{u(x_a)\bar{d}(x_b) + \bar{d}(x_a)u(x_b)}$$



Flavor ID reduces uncertainty in current pol-PDF models.



# Goals of the 1<sup>st</sup> Spin Physics Run

## Establish Stable Asymmetry Measurements

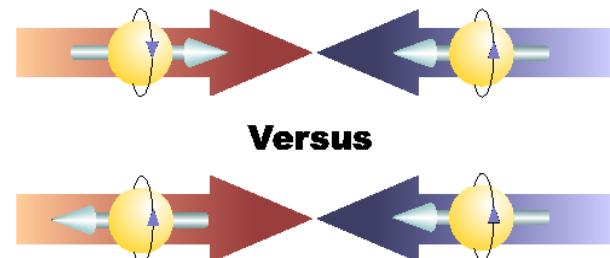
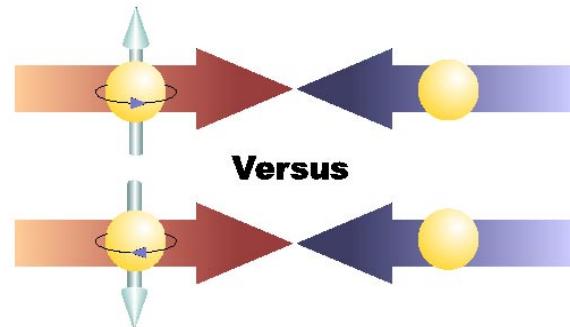
- » Beam Polarization > 50%
- » Luminosity  $\sim 5 \times 10^{30} \text{ cm}^{-2} \text{s}^{-1}$
- » Beam energy: 200 GeV

1 week of transverse polarization  
( $\sim 0.75 \text{ pb}^{-1}$ )

- »  $A_N$  ~ Higher Twist Effects

4 weeks of longitudinal polarization ( $\sim 3 \text{ pb}^{-1}$ )

- »  $A_{LL}$  for pion  $\sim \Delta G$  Measurements
- »  $A_{LL}$  for  $J/\psi$  in muon Arm



# Sensitivity of 1st Spin Physics Run

$$gg \rightarrow gg$$

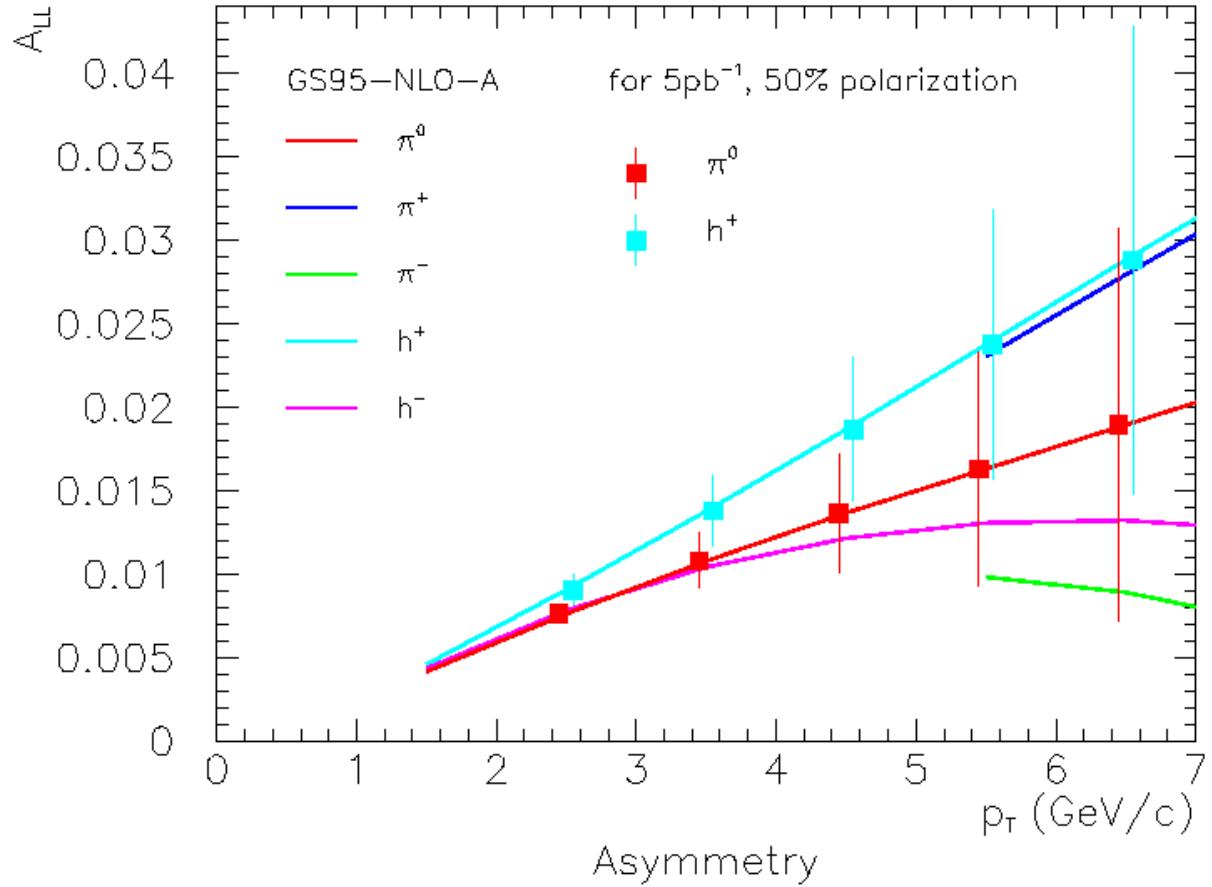
$$\propto \frac{\Delta G}{G} \frac{\Delta G}{G}$$

$$gq \rightarrow gq$$

$$\propto \frac{\Delta q}{q} \frac{\Delta G}{G}$$

$$qq \rightarrow qq$$

$$\propto \frac{\Delta q}{q} \frac{\Delta q}{q}$$



Y. Goto



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UC Riverside  
17 Oct. 2001

# Summary

PHENIX will make major contributions in understanding the spin structure of the nucleon:

- »  $\Delta G$  measurements discussed in talk:
  - Direct  $\gamma$  production
  - Heavy flavor production
- » Quark flavor decomposition

The first RHIC spin run at 200 GeV will begin shortly

- » PHENIX will measure  $A_{LL}$  for neutral pions and charged hadrons.

